Hyperbaric Oxygen Therapy: Role in Gangrene and Acute Wounds

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Abstract

Hyperbaric oxygen is commonly used for the treatment of a wide variety of surgical and non-surgical conditions, and has persuasively proved its high clinical efficiency in many areas. Hyperbaric oxygen therapy (HBOT) has an important role to play as an adjunctive treatment for both acute and chronic wounds. A non-healing wound is one which fails to heal for a variety of reasons including persistent infection, unrelieved pressure, and underlying hypoxia within the wound bed. HBOT has been shown to increase oxygen delivery to the injured tissues, reduce oedema and provide an improved environment for healing and fighting infection. Here, we discuss a case of chronic arterial insufficiency in the lower limb with acute onset gangrene of toe and an acute case of compartment syndrome of the upper limb. HBOT was effectively used as an adjunct to treatment in both the cases. The role of HBOT in reviving compromised tissue in two different cases is discussed.

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Introduction

Complicated acute and chronic wounds are associated with major social, financial and emotional impact for the patient and their family. Same was the situation with both of our cases discussed below. The patients were desperate for a solution to improve their condition after years of pain, physical disability and medication. Hyperbaric oxygen therapy (HBOT) has emerged as an effective adjunct to treatment in many such cases. HBOT has several beneficial roles, one of which is the improvement of the microvascular supply, leading to an increased gaseous diffusion of oxygen to the relatively avascular or ischemic areas. It also aids in fibroblast proliferation and collagen production.Two such case studies are being discussed here to exemplify the successful utilization of HBOT.

Case I

Brief History: On 1 Feb 2013, a 59 yr old male patient, diabetic since 15 years, well controlled with oral hypoglycemic agents reported to the vascular surgeon with complaints suggestive of intermittent claudication in both lower limbs since one year and swelling of right great and second toes since one week. He underwent following investigations:

(a) Routine hematological and biochemical parameters: Normal

(b) Blood Sugar (F &PP): Within normal limits

(c) CT Bifurcation Aortography:

- Right Iliac and lower limb arteries: Complete occlusion of external iliac artery from its origin.
- Left iliac and lower limb arteries:

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Complete occlusion of superficial femoral artery from its origin with reformation in its distal -most course in adductor canal through collaterals.

(d) Doppler study (lower limbs):

- o Right lower limb: Reduced flow over popliteal, posterior tibial and dorsalispedis artery with formation of collaterals.
- o Left Lower limb: Reduced flow over posterior tibial and dorsalispedis artery.

He was diagnosed to have chronic iliac artery stenosis and distal gangrene first right toe and gangrene of second right toe involving more than half of the digit. The patient was a sportsman and had been active all his life. This increase in swelling and gangrene of the lower limb with loss of sensation while being on regular medication had been very distressing for him and adding on to his anxiety. He was referred for HBOT as an adjunct to treatment.

Pre HBOT Examination

He reported for HBOT on 25 March 2013. Following findings were recorded:

General physical examination and vitals were within normal limits. Dorsalispedis and Posterior tibial pulse was not palpable in both the lower limbs. Popliteal pulse was not palpable in right lower limb

(a) Systemic examination revealed no significant findings.

(b) Local examination(Lower limbs):

- Right leg: Skin was pale in appearance. The peripheral pulses (popliteal, posterior tibial and dorsalispedis) were not palpable. No ulcers were present over the calf.
- Right foot:
  - There was oedema and discoloration of skin over the dorsum of foot
  - Second toe had partially necroses with raw tissue over the plantar aspect distally
  - There was discoloration of skin over great toe
  - Tenderness was present over both toes.
- Left leg and foot: Overlying skin appeared pale. Peripheral pulses were absent (posterior tibial and dorsalispedis). There was no evidence of tissue loss (non healing ulcer or gangrene) over the calf and foot.

Fig1: Initial assessment

Fig2: First and second toes with necrosis

Progress and Follow Up

Since the patient was likely to benefit from HBOT, he was taken up for 30 sittings of HBOT (40 min at 2.5 ATA with 2 ft/min ascent and descent rates). After 10 sessions of HBOT there was a marked improvement in the form of reduced swelling over dorsum of foot and improvement in colour of skin over foot and second toe. The patient also had marked relief from local pain. He was recommended to continue HBOT and during the course of next ten sessions, the wound below the nail of great toe on plantar aspect marginalised and there was a

marked decrement in size of the wound. Also, the colour of the skin continued to improve. The pain had reduced markedly by this time. After 30 sessions of HBOT in April 2013, there was a clear demarcation of the affected area in the right second toe and a reduction in size of the wound was observed. The peripheral pulses which were absent at the start of the session were palpable now and there was complete relief from pain.

Doppler study (lower limbs) April 2013:

(a) Right lower limb: Recanalisation of stenosed area with adequate collateralization. Flow pattern over popliteal, posterior tibial and dorsalispedis artery shows triphasic pattern with reduced peak systolic velocity.

(b) Left Lower limb: Recanalisation of stenosed area with adequate collateralization. Flow pattern over posterior tibial and dorsalispedis artery shows triphasic pattern with reduced peak systolic velocity.

Fig3: Reduced swelling with visible veins

Fig4: Reduction in size of gangrene

Case II

Brief History: A 24 yr old male patient, a dentist by profession, reported to the orthopaedicdept of a civil hospital with deformity of the left elbow since childhood following a malunited fracture around 20 yrs back. He was taken up for surgical correction in Feb 2013. He underwent supracondylar corrective dome osteotomy of distal humerus and open reduction internal fixation with bipillar plating.

On the first post operative day at 0600 h the patient complained of swelling and severe pain of the left forearm. He also developed a wrist drop. He was diagnosed to have acute compartment syndrome and underwent an emergency fasciotomy. He however continued to have numbness of hand with loss of muscle function of forearm and wrist drop. Following this the patient was kept on antibiotics for one week and then referred for HBOT.

Pre HBOT Examination

(a) General physical examination and systemic examination were within normal limits.

(b) Local examination of left elbow revealed a varus deformity of left elbow of 10-15 degrees with restricted movement and wrist drop of left hand. The forearm was swollen and almost twice the size of the right forearm. The fasciotomy wound appeared healthy and was approximately 30 cm x 15 cm in size.

Progress and Follow Up

The patient was taken up for HBOT and underwent all the mandatory investigations for HBOT. The investigations being within normal limit the patient was taken up for 30 sittings of HBOT (40 min at 2.5 ATA with 2 ft/min ascent and descent rates). The response to HBOT was good at the start of the treatment with reduced swelling and pain at the wound site. The progress was very promising at the end of 10 sittings wherein the wound showed healthy granulation tissue at its base

along with marked reduction in size. The oozing from wound and purulent discharge had decreased markedly. The patient, however, stopped the treatment for personal commitments and continued the antibiotics. He returned back after a week with worsening of symptoms. The wound area had again developed swelling and purulent discharge with increase in oozing.

Following this the patient was again counseled regarding the importance of taking the complete HBO treatment and its benefits. He was again taken up for HBOT. After 20 sessions, there was a remarkable improvement in the wound with reduced swelling and the wound started healing well. The wrist drop also improved so much so that the patient could conveniently now hold a pen in his hand. He underwent skin grafting at the wound site after completion of HBOT and again underwent 10 more sessions post grafting. The wound had healed completely. The movement at his left elbow was complete and unrestricted by now, with no neurovascular deficit. The patient is now leading a healthy life and is able to conveniently carry out different procedures involving movement of his hand as a dentist.

Discussion

As evident from the above HBOT was effectively used as an adjunctive treatment for promoting wound healing in both acute and chronic cases. It involved delivering 100% oxygen via mask in a pressurized environment. The protocol followed at this Institute is delivering HBOT at a pressure of 2.5 ATA equivalents to 50 feet below sea level.

Supplemental oxygen acts as a nutrient and supports vital processes like angiogenesis, cell motility and extracellular matrix formation. HBOT acts principally by the following methods:

(a) Pressure effects

(b) Vasoconstrictive effects of oxygen

(c) 100% oxygen concentration effects on the diffusion gradient

(d) Hyperoxygenation of ischaemic tissue

(e) Down regulation of inflammatory cytokines

(f) Up-regulation of growth factors

(g) Leukocyte effects

(h) Antibacterial effects [1].

In wound healing, the beneficial effects of oxygen is achieved by increased rate of oxygen diffusion from the capillaries into the wound environment. This is facilitated by increased diffusion gradient of oxygen. Oedema adversely affects the achievement of high oxygen concentrations in the wound and increases the intercapillary diffusion distance. Even a small increase in tissue oedema can dramatically slow the rate of entry of oxygen into the tissues and can

Fig1: Initial Assessment

Fig 2: After HBO Therapy

cause tissue hypoxia. HBOT, thus, breaks the vicious injury cycle of oedema, ischaemia and tissue necrosis. Over a period of time the oxygenation of the chronic wound improves with HBOT.

HBOT induces neovascularisation, which becomes significant after about 14 sittings and continues for years after the HBOT has been ceased [2]. Normal fibroblast proliferation and collagen production requires a partial pressure of oxygen (PO_2) at tissue level to be 20 - 40 mm Hg. Raising this threshold to 40 - 50 mm Hg stimulates a greater degree of neovascularisation which may favour definitive local healing [3]. Neovascularisation occurs by both angiogenesis and vasculogenesis. HBOT increases this rate of new vessel formation which grows from intact mature vessels. The increased oxygen tension in the adjacent tissue supports this process [3]. We can attribute this increased angiogenesis to the improved collateralization during recovery of our first case discussed above.

HBOT potentiates a number of cytokines and growth factors, thus favouring wound healing. It regulates collagen synthesis through pro-al(I) mRNA expression [4] and synergistically enhances the effect of transforming growth factor (TGF)-beta1 and platelet-derived growth factor (PDGF)-beta [5].

Hyperbaric oxygen has a role to play in acute infections by aiding in killing of bacteria by neutrophils or polymorphonuclear cells (PMNs). There is a dramatic fall in the efficiency of bactericidal action of PMNs with a fall in PO_2 [6, 7]. Also, of importance in wound healing is the production of Reactive Oxygen Species (ROS) with HBOT. All wound related cells possess specialized enzymes which generate ROS from oxygen. A low wound PO2 compromises the function of these enzymes and this impairs wound healing [8].

Strauss et al in their study on twenty cases of compartment syndrome post fasciotomy concluded that HBOT aided by speeding up oedema reduction, improving survivability of questionably viable tissue, causing more rapid demarcation of living and dead tissue and accelerating angiogenesis. Similar to our second case who reported improvement in wrist drop, the authors also report two of their patients showing unexpected neurologic recovery [9].

Thus, it is clear that HBOT has following actions which have been used to combat clinical infection:

(a) It activates neutrophils and makes them more efficient

(b) It enhances the activity of macrophage

(c) It aids in inhibiting bacterial growth

(d) It inhibits release of certain bacterial endotoxins

(e) It potentiates the effect of antibiotics

(f) It improves peripheral nerve regeneration by increasing effective oxygen and nutrient delivery.

Conclusion

There is never a single modality which works in healing of either chronic wounds or complicated acute wounds. Hyperbaric oxygen has emerged as a powerful adjunct to treatment for such wounds, acting on injured and healing tissue in a number of ways. Hypoxic tissue, reperfusion injury, compartment syndrome, crush injury, failing flaps, chronic wounds, burns and necrotising infections have all been shown to respond favorably to HBOT. As we learn more about how HBOT benefits wounds by up-regulating growth factors, down regulating cytokines, reducing oedema, and supporting angiogenesis and new tissue in growth, the potential role of HBOT in wound healing would further become clearer. HBOT if available should definitely be incorporated as an adjunct to treatment in management of chronic and acute wounds that are difficult to heal.

References:

1. Zaroff LI, Walker HL, Lowenstein E, Evans BW, Kroos LS. Hyperbaric oxygen in aerobic infections. *Arch Surg* 1965; 91(4): 586-8

2. Skyhar MJ, Hargens AR, Strauss MB, Gershuni DH, Hart GB, Akeson WH. Hyperbaric oxygen reduces edema and necrosis of skeletal muscle in compartment syndromes associated with hemorrhagic hypotension. *J Bone Joint Surg Am* 1986; 68(8): 1218-24.

3. Doctor N, Pandaya S, Supe A. Hyperbaric oxygen therapy in diabetic foot. Journal of Postgraduate Medicine 1992,38:112-114.

4. Ishii Y, Myanaga Y, Shimojo H, Ushida T, Tateishi T. Effects of hyperbaric oxygen on procollagen messenger RNA levels and collagen synthesis in the healing of rat tendon laceration. *Tissue Eng* 1999; 5: 279-86.

5. Zhao LL, Davidson JD, Wee SC, Roth SI, Mustoe TA. Effect of hyperbaric oxygen and growth factors on rabbit ear ischemic ulcers. *Arch Surg* 1994; 129(10): 1043-9.

6. Allen DB, Maguire JJ, Mahdavian M, Wicke C, Marcocci L et al. Wound hypoxia and acidosis limit neutrophil bacterial killing mechanisms. *Arch Surg* 1997; 132(9): 991-6.

7. Babior BM. Oxygen-dependent microbial killing by phagocytes. *N Engl J Med* 1978; 298(13): 659-68.

8. Gordillo GM, Sen CK. Revisiting the essential role of oxygen in wound healing. The American Journal of Surgery 2003, 186(3):259-263.

9. Strauss MB, Hart GB. Hyperbaric oxygen and skeletal muscle compartment syndrome. ContempOrthop; 18: 167-174, 1989.